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TOMATO ANTHRACNOSE

Comparative susceptibility of varieties and their response to spraying

OHIO AGRICULTURAL EXPERIMENT STATION **Wooster, Ohio**

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Comparative Susceptibility of Tomato Varieties to Anthracnose and Their Response to Spraying

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Experiments on the control of anthracnose fruit rot of tomato (Fig. 1) caused by *Colletotrichum phomoides* (Sacc.) Chester, have been carried on in Ohio for the past 6 years. In some of the preliminary tests (1), it was observed that the disease did not attack all varieties of tomatoes with the same degree of severity, although only a few have been found to possess more than a mild degree of resistance. In one of the early experiments, which was conducted at Bowling Green, there were 50, 44, and 35 percent of the fruits affected on Huelsen T19, Rutgers, and Baltimore, respectively.

Experiments on the control of anthracnose by spraying with various fungicides (1, 2) showed that, although Fermate would reduce the amount of fruit loss by approximately 75 percent if it were properly applied, the degree of control was not necessarily

Anthracnose lesions on tomato fruits. Those on tomato at upper left are most typical of mid-season types.

the same on all varieties. With this information as a basis, it was decided to compare a considerable number of varieties as to their susceptibility to anthracnose. To make this comparison, half the plants of each variety were sprayed with the fungicides and their response to control measures was noted (3). These tests, which included the majority of the tomato varieties commonly grown in Ohio as well as many new ones and others not frequently encountered, have been conducted over a period of 4 years.

RESULTS IN 1944

In the summer of 1944, 13 varieties of tomatoes were planted in two-row plots. These plots of 16 plants each (eight in each row) were arranged in a pattern of random distribution with five replications for each variety. Since the factors favoring anthracnose infection are not evenly distributed over even small areas, this plot arrangement was used more to obtain a truly representative picture of the degree of anthracnose infection than to obtain data suitable for statistical analysis. Such analyses were not made of the data.

A field was used where tomatoes had been grown during at least 5 of the 10 preceding years. To insure still further the presence of a plentiful supply of inoculum, a mixture of wheat and oats, on which the causal organism had been grown in pure culture, was scattered over the soil and then raked into the soil around each plant. About 30 days after the earliest variety had bloomed in the first cluster, one of the rows in each of the two-row plots was sprayed with Fermate (2-100) (2). Six applications of approximately 175 gallons per acre were made during the summer at 10-day intervals. The rows in this experiment, and in all of the following experiments, were planted 6 feet apart, with the plants 3 feet apart in the row; they were sprayed with a self-propelled calibrated sprayer equipped with plant guards on wheels 5½ feet apart.

The fruits were harvested at weekly intervals and they were carefully examined, while grading, for the presence of anthracnose lesions. The grade limitations conformed loosely to the specifications used by the Federal inspectors at Ohio processing plants, except that any fruit having one anthracnose lesion or more was classed as a cull. Grades 1 and 2 were then combined and indicated as "usable" in the following tables. The data relative to the 1944 experiment are given in Table 1. The percentages of anthracnose-infected fruits on sprayed and unsprayed plants are shown in adjacent columns and the effect of spraying on yield and on disease

control is indicated. Yield data were not taken with the intention of comparing the productivity of the different varieties but only of indicating varietal response to the effectiveness of spraying for disease control.

TABLE 1.—Relative susceptibility of 13 tomato varieties to infection by anthracnose and their response to spraying with Fermate in 1944.

Variety	Yield of usable* fruits, in tons per acre		Percentage of cull fruits		Percentage of fruits having anthracnose		Response to spraying		
							Percentage reduction in:		Percentage increase in yield
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Culls	Anthracnose	
Baltimore	9.86	8.17	16.5	29.8	4.3	18.4	45	75	21
Cobourg	7.51	6.89	20.0	24.6	4.8	16.4	19	71	9
Earliana	6.81	4.11	19.2	48.6	13.1	43.4	61	70	66
Early Baltimore	10.06	7.32	11.8	20.0	9.6	19.2	41	50	37
Garden State	9.37	7.77	17.3	30.6	10.6	24.1	44	56	21
Golden Queen	8.59	6.70	10.6	29.0	5.5	24.0	64	77	28
John Baer	7.87	7.15	15.7	23.4	2.6	14.2	33	82	10
Red Ponderosa	9.37	7.69	12.2	21.1	5.0	21.6	42	77	22
Red Pear	6.83	6.32	8.2	15.1	7.3	23.8	46	69	8
Rutgers	8.66	7.85	12.3	23.9	8.5	18.9	49	55	10
San Marzano	7.33	5.20	17.9	36.3	9.5	26.5	54	64	41
Stokesdale	8.27	6.46	11.3	29.5	4.6	24.1	62	81	28
Victor	6.50	4.70	21.8	43.1	8.5	34.5	49	75	38
Averages	8.23	6.64	15.0	28.8	7.2	23.8	48	70	24

*The term "usable" fruits as used in this table (and some of the following) loosely represents a combination of Federal grades 1 and 2. The number of fruits usually classed in grade 2 was reduced in many instances by removing any fruit showing an anthracnose lesion and placing it with the culls.

†Percentage of increase in yield in this and following tables refers only to the increase in usable fruits and not to total yield.

The percentage of anthracnose-infected fruits in the unsprayed rows varied from a high of 43.4 in Earliana to a low of 14.2 in John Baer. The corresponding values for the sprayed rows were 13.1 and 2.6 for Earliana and John Baer, respectively. Thus, spraying resulted in a 70 to 82 percent reduction in the disease. The average reduction in anthracnose for all 13 varieties was 70 percent. This corresponds closely to the usual 70 to 80 percent control commonly obtained from the use of Fermate.

The average percentage of anthracnose-infected fruits for all the varieties in the test was 23.8, and about one-half of the varieties showed approximately this amount of disease. Victor, which is a

determinate (self-topping) type, was very susceptible to anthracnose. As will be shown later, most of the determinate varieties are very subject to infection by anthracnose fruit rot.

Earliana, which has a comparatively open type of vine growth, and the determinate Victor were also very high in percentage of cull fruits (all fruits showing one small anthracnose lesion or more at grading time were included among the culls). The lowest percentage of culls was found in Red Pear, a variety having comparatively small fruits that are held well off the ground by the vine which bears them. This characteristic is important, since contact with the soil is know to promote infection by anthracnose and other soil rots. In this experiment, spraying reduced the average percentage of cull fruits by approximately one-half and increased the yield of salable fruit by approximately 1.5 tons per acre, or 24 percent.

RESULTS IN 1945

The experiment of 1944 was repeated in 1945 in the same manner, except that Zerlate was substituted for Fermate, in the same field with 15 varieties. The harvesting and grading procedure was also the same. The data relative to this experiment are given in Table 2.

TABLE 2.—Relative susceptibility of 15 tomato varieties to anthracnose infection, and the reduction in disease brought about by spraying with Zerlate in 1945.

Variety	Yield of usable fruits, in tons per acre		Percentage of cull fruits		Percentage of fruits having anthracnose		Response to spraying		
							Percentage reduction in:		Percentage increase in yield
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Culls	Anthracnose	
Baltimore	10.45	8.42	19.6	28.2	0.7	3.2	32	78	24
Bounty	11.21	7.57	27.0	44.3	1.6	21.8	39	93	48
Cobourg	10.55	8.02	19.8	36.1	1.2	10.0	45	88	32
Early Baltimore	11.09	10.72	16.0	17.8	0.4	5.4	10	91	4
Fordhook Hybrid	10.92	9.56	26.6	35.6	1.8	14.1	25	87	14
Garden State	9.93	8.96	20.6	25.5	2.3	6.2	19	63	11
Jubilee	6.86	6.52	17.5	18.6	1.3	3.0	6	57	6
Marglobe	12.11	11.74	10.8	17.5	0.7	4.0	38	83	3
Ponderosa	6.61	4.88	22.2	35.3	4.4	13.4	37	67	35
Pritchard	11.03	9.50	19.7	22.6	1.5	4.9	13	69	16
Rutgers	12.95	9.94	10.1	16.0	0.7	5.9	40	88	30
Scarlet Dawn	12.23	11.74	17.4	22.0	0.8	3.4	20	76	4
Stokesdale	9.57	8.93	18.2	21.0	1.5	5.4	13	72	7
Stone	8.35	6.31	20.4	30 0	1.4	4.3	32	68	32
Valiant	12.08	11.43	18.4	19.4	2.3	4.3	5	47	6
Averages	10.3	9.0	19.0	25.0	1.5	6.6	24	77	14

Infection by anthracnose was much less severe in 1945 than in 1944. The largest percentage of infected fruits occurred in Bounty, where it was 21.8 percent. From 3 to 5 percent of infection was recorded for many varieties in 1945; the average infection in the unsprayed rows was 6.6 percent, as compared with four times that amount in 1944. The average precentage of reduction in infection due to spraying was slightly greater than that of 1944. In 1945, more fruits were classed as culls than in 1944, due to causes other than anthracnose. Largely because of this fact, the reduction in percentage of culls obtained by spraying was not as marked. This, in turn, reduced the average increase in yield due to spraying.

RESULTS IN 1946

The study of varietal susceptibility to anthracnose was expanded in 1946 to include 48 more or less common varieties. In addition, about 30 new varieties and hybrids were included in a search for resistance. The planting arrangements were much like those of the two previous years, and alternate rows were sprayed at weekly intervals with Zerlate. The season was very dry and yields were comparatively low. Anthracnose infection was plentiful in the fruits from the unsprayed plants of many of the varieties used. The disease was very well controlled on most varieties by spraying. The resulting average reduction of infection of 84 percent is somewhat better than usual. The fruit rots as a group were reduced to such an extent that the sprayed plots showed an average of only one-fourth as many culls as those that had been left untreated. The average increase in the yield of usable fruits due to spraying was approximately 50 percent, or 3 tons per acre. The data relative to this experiment are given in Table 3.

The 48 varieties included ten pink and four yellow varieties. When the data relative to these pink, yellow, and red varieties were averaged (see data near the end of Table 3), it was found that the pink varieties, as a group, were more susceptible to anthracnose than the red or yellow ones and that the yellow varieties were least susceptible. The culls varied in the same order. The average percentage of fruits showing anthracnose among the pink, red, and yellow varieties were 25, 23, and 9, respectively, and the culls made up 30, 24, and 12 percent, respectively, of the total picked. The yield of usable fruits was increased most by spraying the pink varieties and least on the yellow ones.

TABLE 3.—Relative susceptibility of 48 tomato varieties to infection by anthracnose fruit rot (unsprayed values) and the control of this and other fruit rots furnished by Zerlate in 1946.

Variety	Yield of usable* fruits, in tons per acre		Percentage of cull fruits		Percentage of fruits having anthracnose		Response to spraying		
							Percentage reduction in:		Percentage increase in yield
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Culls	Anthracnose	
Baltimore	6.9	3.7	7.8	17.7	3.1	10.7	56	71	86
Beauty	5.9	3.6	15.7	30.3	12.5	21.0	48	45	64
Bison	4.1	2.1	16.0	53.9	7.8	70.2	69	90	95
Bounty	6.8	2.9	5.6	46.8	5.2	59.9	88	91	134
Burbank	7.4	3.0	14.5	50.0	9.3	51.8	71	82	147
Burpee Hybrid	9.4	7.7	4.0	20.3	0.6	16.5	80	96	22
Chalk's Early Jewel	6.9	4.2	4.9	22.6	1.9	16.0	78	88	64
Clark's Special Early	8.8	5.3	2.4	19.5	1.0	16.4	88	94	66
Cobourg	6.6	4.4	6.6	13.1	2.6	18.3	50	86	50
Cooper's Special	6.1	4.7	4.6	18.3	3.3	22.2	75	85	30
Dwarf Champion	5.3	4.9	4.3	9.0	1.0	8.6	52	88	9
Dwarf Stone	7.2	3.9	1.5	5.2	1.0	5.1	71	80	85
Earliana	6.0	3.6	19.1	55.6	17.0	56.5	66	70	67
Early Detroit	5.5	3.7	12.0	32.3	5.9	25.2	63	77	49
Early Baltimore	7.8	5.0	1.9	19.5	0.3	14.6	90	98	56
Fordhook Hybrid	6.9	4.0	16.4	36.0	10.5	39.1	54	73	73
Garden State	10.8	6.2	2.7	25.4	0.8	23.8	89	97	74
Globe	7.1	4.8	3.1	28.6	2.0	26.1	89	92	48
Gold Ball	11.5	9.2	1.1	5.7	0.2	3.9	81	95	25
J T D	8.2	4.3	3.6	33.8	1.7	24.3	86	93	91
Grothen's Globe	5.3	3.3	7.3	38.8	2.8	41.6	84	93	61
Gulf State Market	8.6	3.5	6.0	36.7	2.9	39.7	84	93	146
Huelsen T19	14.0	6.3	7.6	25.7	2.2	20.9	69	90	122
John Baer	8.3	7.2	3.2	10.2	5.3	9.9	69	47	15
Jubilee	8.6	7.6	2.6	13.0	1.0	8.0	80	88	13
Golden Queen	9.6	5.9	4.7	27.8	8.6	19.6	83	56	63
Magnus	10.0	7.2	3.7	19.6	0.5	13.7	81	96	39
Marglobe	10.6	10.0	4.0	17.6	1.2	16.4	77	93	6
Marhio	12.6	6.8	6.7	30.5	3.7	27.1	78	86	85
Mingold	12.9	7.9	2.3	12.7	1.4	11.9	82	88	63
New Stone	10.7	7.7	3.2	8.6	0.7	5.1	63	94	39
Oxheart	11.3	1.8	8.5	58.6	2.4	28.0	85	92	528
Pan America	7.8	6.0	2.2	11.9	1.6	18.3	82	91	30
Pearson	7.0	6.4	1.9	18.9	3.9	11.1	90	67	9
Penn State	7.7	3.9	7.6	33.7	6.0	35.0	77	89	97
Pink Ponderosa	5.0	2.8	8.1	36.3	5.2	38.8	78	87	79
Red Ponderosa	10.3	8.2	4.6	12.0	3.8	8.2	62	54	26
Pritchard	6.7	4.9	2.2	30.2	1.6	29.4	93	95	37
Rutgers	12.9	8.3	3.3	14.4	1.7	12.9	70	87	55
San Marzano	12.3	8.0	6.6	26.2	4.2	20.0	75	79	54

Variety	Yield of usable fruits, in tons per acre		Percentage of cull fruits		Percentage of fruits having anthracnose		Response to spraying		
							Percentage reduction in:		Percentage increase in yield
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Culls	Anthracnose	
SM x Miss.*	8.9	7.6	3.4	16.0	0.8	12.2	79	94	17
Scarlet Dawn	8.9	7.6	2.8	12.1	0.2	10.0	77	98	17
Sioux	7.2	6.1	4.2	12.4	2.7	11.1	66	76	18
Stokesdale	7.2	6.0	3.2	13.7	1.8	8.0	77	78	20
Valiant	5.6	4.3	3.9	18.2	1.8	17.8	68	90	30
Victor	5.2	2.7	6.4	34.3	6.8	32.6	81	79	93
Winsall	5.9	3.4	7.1	40.2	2.3	39.8	82	94	74
Wisconsin 55	11.9	5.5	7.6	13.7	5.7	12.4	45	55	116
Averages†									
All varieties	8.2	5.2	5.7	24.1	3.5	22.6	76	84	58
10 pink varieties	7.7	4.4	7.3	30.0	3.9	25.0	76	84	75
34 red varieties	8.3	5.3	5.7	23.8	3.5	23.4	78	85	55
4 yellow varieties	8.5	6.1	2.1	11.8	2.2	8.7	82	75	39
7 determinate varieties	6 2	3.9	6.3	22.7	4.9	35.8	82	85	71
7 indeterminate varieties	9.5	7.0	4.0	14.8	1.8	10.8	71	82	41
7 early to med. early varieties	6.4	3.6	11.6	35.7	6.9	37.9	66	82	78
7 med. to late varieties	9.9	6.3	4.1	17.8	1.9	15.0	72	84	48
7 vines more open than average variety	7.3	4.3	10.1	29.8	6.6	28.3	66	78	66
7 vines more dense than average variety	9.7	7.0	3.2	20.6	1.2	18.2	80	94	45
14 quickly defoliating varieties	6.9	3.9	8.7	34.8	5.8	36.5	75	83	86
14 slowly defoliating varieties	8.8	6.1	5.4	18.8	3.1	16.8	69	81	52

*San Marzano x Mississippi

†Varieties grouped by characteristics:

10 pink varieties—Beauty, Cooper's Special, Dwarf Champion, Early Detroit, Globe, Gulf State Market, Marhio, Oxheart, Ponderosa, and Winsall.

4 yellow varieties—Gold Ball, Golden Queen, Jubilee, and Mingold.

7 determinate varieties—Bison, Bounty, Cooper's Special, Pearson, Penn State, Pritchard, and Victor.

7 indeterminate varieties—Baltimore, Early Baltimore, Marglobe, New Stone, Red Ponderosa, Rutgers, and Stokesdale.

7 early to medium-early varieties—Bison, Chalk's Early Jewel, Cobourg, Earliana, Early Detroit, Fordhook Hybrid, and Gulf State Market.

7 medium-late to late varieties—Baltimore, Garden State, Globe, Marglobe, New Stone, Red Ponderosa, and Rutgers.

7 varieties more open than average—Chalk's Early Jewel, Early Detroit, Earliana, Fordhook Hybrid, Pink Ponderosa, Scarlet Dawn, and Wisconsin 55.

7 varieties more dense than average—Garden State, Globe, Magnus, Marglobe, New Stone, Pritchard, and Rutgers.

14 quickly defoliating varieties—Bison, Bounty, Clark's Special Early, Earliana, Victor, Burbank, Chalk's Early Jewel, J T D, Gulf State Market, Penn State, Fordhook Hybrid, Grothen's Globe, Cobourg, and John Baer.

14 slowly defoliating varieties—New Stone, Dwarf Stone, Winsall, Pink Ponderosa, Marhio, Rutgers, Marglobe, Red Ponderosa, Magnus, Pan America, Wisconsin 55, Dwarf Champion, Beauty, and Stokesdale.

This experiment again demonstrated that the fruits produced on vines of determinate growth seemed to be more susceptible to anthracnose than those from vines of indeterminate habit. The average degree of infection on the unsprayed plants of seven determinate varieties was 35.8 percent, whereas it was only 10.8 percent for seven varieties of indeterminate growth. The percentage of cull fruits varied similarly—23 and 15 percent, respectively, on the two vine types. Spraying the determinate types of tomatoes improved them greatly, giving an 85 percent reduction in disease and a 71 percent increase in the yield of usable fruit. The extent of this improvement was probably correlated with an increase in the amount and persistence of foliage cover for the fruits, since the use of Zerlate considerably delayed defoliation by Alternaria blight. The apparent importance of good foliage condition in holding anthracnose infection to a minimum is indicated in some of the other comparisons made at the end of Table 3.

The average infection on the unsprayed plots of seven early varieties was 38 percent; whereas it was only 15 percent on another group of seven later maturing ones. The foliage condition was better throughout the season on the late varieties and the fruits were less exposed to direct sunlight. In another group of seven tomato varieties with comparatively open and sparse foliage, the average anthracnose infection on unsprayed plants was 28 percent, as compared with 18 percent on a group having more dense foliage. Spraying increased the yield of good fruits 66 percent on the open plants, but only 45 percent on the plants with heavier foliage.

These comparisons were carried still further by selecting 14 varieties that were completely or nearly defoliated on September 15 and comparing them with others that still retained 30 to 50 percent of their original foliage at that time (Table 4). Thirty-seven percent of the fruits on the defoliated varieties were infected at picking time, whereas this percentage dropped to 17 percent on those that retained more foliage for a longer period. The yield increases due to spraying followed the usual pattern; namely, the average for varieties defoliated early was 86 percent, as contrasted with only 52 percent for those with higher foliage scores.

As a final summary of the apparent relationship between vine characteristics and susceptibility to anthracnose infection, the values for determinate growth, early maturity, open growth, and early defoliation were averaged and compared with those for vines of indeterminate growth, late maturity, dense foliage, and late

TABLE 4.—Percentage of dead foliage on sprayed (Zerlate) and unsprayed plants of 48 tomato varieties on September 15, 1946.

Variety	Percentage of foliage dead on Sept. 15		Variety	Percentage of foliage dead on Sept. 15	
	Sprayed	Unsprayed		Sprayed	Unsprayed
Bison	81	100	Pritchard	42	72
Bounty	64	100	S M x Miss	33	72
Clark's Sp Ey	60	100	Burpee Hybrid	36	71
Earliana	78	100	Mingold	33	70
Victor	74	100	San Marzano	38	70
Burbank	53	98	Globe	39	68
Chalk's Ey Jewel	59	98	Oxheart	33	68
J T D	72	98	Stokesdale	41	68
Gulf State Market	44	92	Beauty	30	65
Penn State	63	92	Dwarf Champion	38	65
Fordhook Hybrid	49	90	Wisconsin 55	34	65
Grothen's Globe	62	90	Pan America	24	64
Cobourg	52	88	Magnus	29	60
John Baer	59	88	Red Ponderosa	29	60
Sioux	54	88	Marglobe	19	59
Cooper's Special	33	82	Jubilee	22	58
Garden State	34	82	Rutgers	19	57
Scarlet Dawn	32	82	Marhio	22	56
Baltimore	43	80	Pink Ponderosa	21	55
Early Baltimore	44	79	Winsall	22	55
Huelsen T 19	51	78	Dwarf Stone	33	52
Valiant	50	78	Golden Queen	24	50
Early Detroit	51	75	Gold Ball	23	48
Pearson	34	72	New Stone	19	48

defoliation. The average values for percentage of anthracnose infection, of culls on unsprayed plants, and of increase in yield by spraying were 38, 38, and 73, respectively, for the plants of determinate growth and 21, 17, and 37 percent for those of indeterminate growth. In other words, anthracnose and culls were only about half as plentiful on varieties with good foliage cover as on those varieties on which fruit exposure was early and excessive. Also, spraying increased the yield nearly twice as much on varieties with poor foliage condition, as on those with heavier and more persistent foliage.

TOUGHNESS OF EPIDERMIS AND SUSCEPTIBILITY

Since the susceptibility of tomato fruits to infection by anthracnose is apparently increased by excessive exposure to sunlight and early contact with the soil, it seems likely that the resistance of the epidermis to penetration of the fungus must in some way

be lowered. Sunburned fruits, or those exposed to excessive sunlight, may develop a series of small cracks through which infection could take place more easily, and the epidermis with its protecting cuticle might be worn thin by soil abrasion or biological and chemical action. Also, it is possible, of course, that varietal variations in susceptibility may be due in some way to heritable differences in the epidermis or cuticle.

This suggested the possibility that a correlation might exist between resistance to mechanical puncture and susceptibility to infection. Resistance to puncture was determined with a Chatillon push-pull gauge which measured the pressure in grams required to push a steel pin 0.032 inch in diameter through the epidermis of ripe fruits of the different varieties included in the 1946 experiment. The data given in Table 5 represent the averages of five determinations made on each of four fruits on two different dates (40 in all for each variety). An effort was made to pick fruits of

TABLE 5.—Resistance of epidermis to mechanical puncture, as measured in grams by a push-pull gauge.

Variety	Resistance to puncture in grams	Variety	Resistance to puncture in grams
Dwarf Champion	188	Stokesdale	153
Grothen's Globe	176	Valiant	153
Golden Queen	173	Sioux	152
Early Baltimore	170	Burpee Hybrid	150
Winsall	169	Clark's Special Early	149
Pan America	167	Earliana	149
Cobourg	166	Fordhook Hybrid	149
Early Detroit	166	Bison	148
John Baer	166	Dwarf Stone	148
Chalk's Early Jewel	164	Gold Ball	147
S. M. x Miss.	163	Gulf State Market	147
Marhio	161	Cooper's Special	144
Victor	161	Pritchard	144
Beauty	160	Garden State	143
San Marzano	160	J T D	143
Burbank	157	Bounty	139
Magnus	157	Mingold	138
Marglobe	157	Rutgers	136
New Stone	157	Wisconsin 55	136
Baltimore	156	Penn State	135
Jubilee	155	Huelsen T 19	134
Pearson	155	Oxheart	129
Globe	153	Red Ponderosa	128
Scarlet Dawn	153	Pink Ponderosa	126

a comparable degree of ripeness in each variety, but this proved difficult with the wide variations in fruit shape, size, color, and firmness that existed in this collection of varieties.

One of the varieties most resistant to puncture was Dwarf Champion and it also showed a rather low percentage of anthracnose infection in the field (8.6 percent against an average of 22.6 for 48 varieties). On the other hand, Grothen's Globe, with a puncture reading of 176 grams (one of the highest), showed 41.6 percent of anthracnose on unsprayed plants; Red Ponderosa, with one of the lowest puncture values of all (128 grams), showed only 8.2 percent of its fruits infected. Ten of the varieties most susceptible to anthracnose when unsprayed in the field, with an average infection percentage of 45.3, had an average puncture value of 153 grams, whereas 10 other varieties with an average field infection of only 9.6 percent had an almost identical puncture value of 154.4 grams. Thus, these data indicate quite definitely that there is little or no correlation between resistance to puncture and susceptibility to infection by anthracnose fruit rot.

THE ESCAPE FACTOR

The possible importance of the escape factor, aided by certain vine characteristics, in regulating the amount of infection that occurs on the fruits of some varieties in the field was emphasized in an experiment in which five well-ripened fruits of each variety were artificially subjected to infection in the greenhouse and left exposed on a bench for several days. In general, those varieties which were very susceptible in the field (such as Bison, Earliana, Penn State, Golden Queen, Fordhook Hybrid, and Gulf State Market) also showed a large number of lesions in the greenhouse. However, others like Dwarf Champion and New Stone which showed less than 10 percent of diseased fruits in the field were the most susceptible varieties included in the test on artificial inoculation. On the other hand, comparatively susceptible varieties, such as Huelsen T19, Globe, JTD, and Pritchard (all of which showed over 20 percent of anthracnose in the field) developed only comparatively few lesions under artificial conditions. Some of the relationships between fruit characters and susceptibility to anthracnose infection will be discussed in a future article.

TABLE 6.—Susceptibility of 30 varieties of tomatoes (some old and some new) to fruit rots, particularly anthracnose, and their response to spraying with Zerlate in 1947.

Variety	Yield of usable fruits, in tons per acre		Percentage of cull fruits		Percentage of fruits having anthracnose		Response to spraying		
							Percentage reduction in		Percentage increase in yield
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Culls	Anthracnose	
Baltimore	6 60	3 15	15	52	2	15	64	87	103
Bounty	4 55	1 55	23	60	8	44	62	82	194
Cleo	7 00	3 70	13	47	2	15	72	87	89
Clinton	8 75	3 85	15	48	3	17	69	82	127
Dwarf Champion	2.60	1 55	21	50	2	11	58	82	68
Earliana	10.30	3 80	21	52	3	34	60	91	197
Earliana x Rutgers	7 65	5 05	13	38	2	23	66	91	52
Earliana x Valiant	8 10	4 50	16	46	2	25	65	92	80
Early Baltimore	4.45	1 75	16	43	1	7	63	86	154
Early Red	8 65	5 05	9	32	1	11	72	91	71
Firesteel	4.65	2.15	21	49	1	21	57	95	116
Fordhook Hybrid	8 80	4.20	13	33	2	22	60	91	109
Garden State	6.30	3 80	13	46	2	19	72	88	66
Gem	3.65	2 25	28	55	6	24	49	75	62
Gulf State Market	5.15	2.30	18	43	2	19	58	89	124
Jefferson	6.00	3 40	15	60	2	31	75	93	150
Jubilee	4.95	0 60	13	61	0	12	79	100	725
Long Red	11.80	9 10	6	16	1	6	62	83	30
100 Certified	4.10	2 05	16	47	1	8	66	87	100
Ontario	6 75	3 35	15	47	2	18	68	89	101
OSU 3	5.30	2 30	16	44	0	7	64	100	130
Quebec	6 30	4 25	7	26	2	15	72	87	47
Red Jacket	6 75	3 50	11	42	1	21	74	95	93
Rutgers	4 20	1 65	20	58	1	16	64	94	155
S M x Miss	9 75	6 45	6	27	1	14	78	93	51
651	4 75	2 70	24	48	5	35	50	86	76
Stokesdale	6 65	4 25	9	39	1	11	77	91	56
Stokes Hybrid	7 25	2 75	13	50	1	20	74	95	164
Stokesdale x Rutgers F_2	6 25	2 10	16	51	0	18	69	100	200
Indeterminate Dwarf	3 65	1 35	29	62	2	16	53	87	70
Averages	6 39	3 28	16	44	2	19	64	90	95

RESULTS IN 1947

In 1947, thirty varieties of tomatoes, over half of which had not been previously tested (since many of them were only introduced during 1945 and 1946), were compared for susceptibility of the fruits to infection by anthracnose. These data are presented in Table 6. Late blight also appeared in this planting during the last half of the picking period and some data were obtained on the extent to which the leaves and fruits of the different varieties under test were attacked by this disease. These data are given in Table 7, together with a record of the degree of defoliation which had occurred on two different dates. Ripe fruits infected with late blight at the date of the first frost appear as culls in the data of Table 6, but they are not listed separately there.

In 1947 the average percentage of anthracnose on all varieties was about the same as in 1946, and this was rather high. The maximum infection occurred on Bounty, a very susceptible variety, and was followed by such varieties as "651", Earliana, Jefferson, Earliana x Valiant, Gem, and Earliana x Rutgers, in descending order. Earliana, as indicated above, was another very susceptible variety, and these data indicate that this characteristic was transmitted by hybrids having Earliana as one of the parents. Anthracnose was reduced on these seven varieties from an average of 31 percent of the fruits on unsprayed rows to 4 percent on rows sprayed with Zerlate (2-100) at seven weekly intervals. Thus, in these seven varieties spraying resulted in about 87 percent reduction in infection as compared with 90 percent for all 30 varieties. In other words, Zerlate gave good control.

In general, those varieties which showed early defoliation (Table 7) were most susceptible to anthracnose, whereas those which held their foliage until later in the season were least attacked by this fruit rot. This may have been partly a temperature factor, since the late-maturing varieties ripened the majority of their fruit during cooler weather. It is also likely that the exposure of fruit to intense sunlight had the same effect as in 1946 when varieties that both defoliated and ripened early showed a high percentage of anthracnose on the fruits. The data of Table 6 show that the comparative percentages of anthracnose were 26 percent on the 10 varieties with earliest defoliation, followed by 18 percent on an intermediate group of 10, and only 11 percent on the 10 varieties with the least defoliation.

TABLE 7.—Influence of spraying with Zerlate on the amount of late blight on ripe and green tomato fruits and on defoliation of the plants by early and late blights in 1947.

Variety	Percentage of foliage alive on				Percentage of fruits affected by late blight			
	August 25		September 7		Ripe		Green (after frost)	
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed
Baltimore	88	65	75	38	6	14	31	60
Bounty	78	48	40	13	1	3	6	20
Cleo	80	65	75	50	2	19	35	100
Clinton	80	68	73	45	4	22	30	48
Dwarf Champion	78	65	70	48	6	26	33	44
Earliana	80	53	63	28	3	5	3	16
Earliana x Rutgers	80	60	65	33	5	5	10	18
Earliana x Valiant	80	58	63	28	4	6	4	22
Early Baltimore	90	73	80	50	6	39	24	90
Early Red	83	65	68	38	1	9	9	37
Firesteel	80	55	53	20	5	11	6	23
Fordhook Hybrid	80	58	63	28	1	9	16	22
Garden State	90	80	80	58	6	23	14	35
Gem	78	50	48	13	4	11	5	20
Gulf State Market	83	60	70	38	3	21	28	54
Jefferson	88	68	73	38	6	21	16	54
Jubilee	88	70	75	46	9	49	36	71
Long Red	90	75	75	53	1	5	3	20
100 Certified	90	73	73	46	8	23	21	38
Ontario	85	60	73	35	8	23	24	31
OSU 3	88	75	78	48	7	32	24	90
Quebec	80	58	60	25	0	1	18	58
Red Jacket	78	50	58	23	3	7	5	18
Rutgers	85	68	78	45	14	39	22	63
SM x Miss.	80	65	75	53	1	7	11	40
651	78	50	53	15	2	6	6	14
Stokesdale	85	73	73	40	5	21	30	61
Stokes Hybrid	88	70	73	48	6	20	19	44
Stokesdale x Rutgers F_2	85	73	78	40	7	24	24	59
Indeterminate Dwarf	83	65	68	28	11	41	47	80
Averages					5	18	15	45

As indicated earlier, the percentage of culls on unsprayed plots was regulated to a considerable extent by the amount of both anthracnose and late blight infection. The relative influence of the two diseases in determining the percentage of culls varied con-

siderably with the variety. Bounty, Jefferson, Jubliee, and an indeterminate dwarf (last in the list of 30 varieties in Table 6) all showed at least 60 percent of culls among unsprayed fruits. The first two varieties named were in this class because of a high anthracnose infection, but the last two were so classed because of a high degree of susceptibility to late blight. The average reduction in culls resulting from spraying was approximately 67 percent for these four varieties. This corresponded closely to the 64 percent obtained for all 30 varieties. Long Red was outstanding among these 30 varieties for its low percentage of culls on both unsprayed and sprayed plots.

The yield of usable fruits of the four varieties—Bounty, Earliana, Jubilee, and Stokesdale x Rutgers F_2—was about trebled by spraying with Zerlate. This was due largely to the control of anthracnose on Bounty and Earliana and of late blight on Jubilee and Stokesdale x Rutgers F_2. It is interesting to observe that spraying these 30 varieties resulted in an average increase of 11 percent in fruit number, a total yield increase of 30 percent, and a net (usable) yield increase of 95 percent. Culls were reduced by 64 percent, anthracnose was reduced by 90 percent, and late blight was reduced by 70 percent. The increase in fruit number, together with some increase in size of the fruit, on sprayed vines accounted for the yield increase of 30 percent over that on untreated plants. The decrease in culls by spraying saved enough fruits so that the yield of usable tomatoes was nearly twice as great from sprayed as from unsprayed plants. In addition, there were six times as many green fruits left on the treated vines as on the unsprayed ones after the first frost in late September.

Fruit number was increased to the greatest extent by spraying such early varieties as Bounty, Earliana, Firesteel, Fordhook Hybrid, Quebec, and "651". The average increase was 45 percent. Fordhook Hybrid showed the greatest increase (72 percent) of any single variety. A few varieties such as Garden State and Rutgers showed little or no increase.

RESULTS WITH FIVE PROCESSING VARIETIES

In Ohio, comparatively few tomato varieties are planted for processing; therefore, it was decided to compare only five of these varieties for susceptibility to anthracnose and their response to spraying with Fermate or Zerlate. The data for 3 years are given in Table 8.

TABLE 8.—The relative susceptibility of five varieties of processing tomatoes to anthracnose infection at Wooster over a period of 3 years.

Variety	Yield of usable fruits, in tons per acre		Percentage of cull fruits		Percentage of fruits having anthracnose		Response to spraying		
							Percentage reduction in:		Percentage increase in yield
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Culls	Anthracnose	
1944									
Cobourg	7 5	6 9	20.0	24.6	4 8	16 4	19	71	9
Stokesdale	8.3	6.5	11.3	29.5	4.6	24.1	62	81	28
Baltimore	9.9	8 2	16.5	29.8	4.3	18.4	45	75	21
Garden State	9.4	7.8	17.3	30 6	10.6	24.1	44	56	21
Rutgers	8.7	7 9	12.3	23.9	8 5	18 9	49	55	10
1945									
Cobourg	10 6	8.0	19.8	36 1	1.2	10.0	45	88	32
Stokesdale	9.6	8 9	18.2	21.0	1 5	5.4	13	72	7
Baltimore	10.5	8.4	19.6	28.2	0 7	3.2	32	78	24
Garden State	9.9	9 0	20.6	25 5	2 3	6.2	19	63	11
Rutgers	13.0	9.9	10.1	16.0	0 7	5.9	40	88	30
1946									
Cobourg	6.6	4.4	6.6	13.1	2.6	18.3	50	86	50
Stokesdale	7.2	6.0	3.2	13.7	1.8	8.0	77	78	20
Baltimore	6.9	3.7	7.8	17.7	3.1	10.7	56	71	86
Garden State	10.8	6.2	2.7	25.4	0.8	23.8	89	97	74
Rutgers	12.9	8.3	3.3	14 4	1.7	12.9	70	87	55
Averages									
Cobourg	8.2	6.4	15.5	21.3	2.9	14.9	23	81	28
Stokesdale	8.4	7.1	10.9	21.4	2.6	12.5	49	79	18
Baltimore	9.1	6.8	14.6	25.2	2.7	10.8	42	75	34
Garden State	10.0	7.7	13.5	27.2	4.6	18.0	50	74	30
Rutgers	11.5	8.7	8.6	18.1	3.6	12.6	52	76	32

When the data for these three trials were averaged, Garden State showed the largest percentage of anthracnose-infected fruits, both in sprayed and unsprayed plots. Cobourg was second, Stokesdale and Rutgers were close thirds, and Baltimore had the least. The percentage of reduction in anthracnose obtained by spraying was similar for all but Stokesdale; this responded the least. Garden State also showed the highest percentage of cull fruits, but Rutgers had the fewest culls.

Garden State was somewhat unusual in these tests in its susceptibility to anthracnose since comparatively few of its fruits became infected during the first half of the season when many of the fruits were held off the ground and the foliage cover was heavy. Later in the season, after the vines had lost many of their leaves and the fruit load became heavy enough that many of the fruits came in contact with the soil, the percentage of infection increased rapidly. These characteristics are, of course, true of nearly all varieties, but anthracnose infection apparently increases to a lesser degree in most varieties than in Garden State.

In 1945, Garden State showed a greater increase in anthracnose infection as the season advanced than any of the other 15 varieties under test. It was followed in turn by Golden Jubilee and Marglobe, both of which are varieties usually having comparatively few fruits affected by anthracnose during the first half of the ripening period. None of the 15 varieties showed a higher percentage of infection during the first half of the picking season than during the last half, but on early varieties like Bounty and Fordhook Hybrid the increase in percentage of affected fruits was least as the season advanced. In an average of a series of comparisons like those reported in Tables 7 and 8, Garden State showed 7 percent of the fruits affected with anthracnose during the first half of the season; this increased to 31.8 percent for the second half, or an increase of 350 percent. Corresponding increases for Cobourg, Stokesdale, Baltimore, and Rutgers were 170, 150, 140, and 160 percent, respectively. Garden State, on the other hand, showed the lowest percentage of increase in cull fruits as the season advanced.

These five commercial processing varieties were used in three experiments in Ohio in 1946 in a series of experiments designed to test the comparative ability of various fungicides to control anthracnose fruit rot and other diseases of tomato vines and fruits. Some of the results of these experiments, arranged according to varieties, are given in Table 9.

Garden State was again the most susceptible to infection by anthracnose in the unsprayed plots. However, it responded more to spraying than Rutgers; Rutgers showed more anthracnose in the sprayed plots than did Garden State. The percentage of cull fruits were considerably greater for Garden State than for any of

TABLE 9.—The average response of five canning varieties of tomatoes to spraying in Ohio in 1946.

Variety	Yield of usable fruits, in tons per acre		Percentage of cull fruits		Percentage of fruits having anthracnose		Response to spraying		
							Percentage reduction in:		Percentage increase in yield
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Culls	Anthracnose	
Fremont									
Cobourg	19.1	17.8	7.8	12.1	3.7	6.8	36	46	7
Stokesdale	21.6	20.5	8.0	10.8	4.0	9.3	26	57	5
Baltimore	23.4	22.5	10.0	14.5	3.6	11.7	31	69	31
Garden State	23.1	15.9	11.3	29.0	9.2	27.9	61	67	11
Rutgers	19.2	17.0	10.3	22.0	11.0	23.5	53	53	11
Irrigated Plot at Wooster									
Cobourg	9.9	7.8	4.6	15.6	1.3	9.8	71	87	21
Stokesdale	13.7	12.2	3.3	15.3	1.1	8.3	78	87	11
Baltimore	12.1	9.9	2.6	13.6	0.9	11.0	81	92	18
Garden State	13.8	11.0	2.9	24.1	1.4	21.6	88	94	20
Rutgers	12.0	11.5	4.6	15.8	2.0	9.8	71	80	4
Wooster									
Cobourg	14.6	14.2	9.0	10.9	0.4	1.1	17	64	3
Stokesdale	18.2	14.9	2.5	8.7	0.4	2.6	71	85	18
Baltimore	18.9	18.8	3.8	9.3	0.3	1.8	59	83	1
Garden State	17.8	17.8	4.3	12.7	0.4	7.6	66	95	0
Rutgers	15.6	12.8	2.1	10.0	0.7	7.0	48	90	18
Averages									
Cobourg	14.5	13.3	7.1	12.9	1.8	5.9	45	70	9
Stokesdale	17.8	15.9	4.6	11.6	1.8	6.7	60	73	12
Baltimore	18.1	17.1	5.5	12.5	1.6	8.2	56	81	6
Garden State	18.2	14.9	6.2	21.9	3.7	19.0	72	81	18
Rutgers	15.6	13.8	5.7	15.9	4.6	13.4	64	66	12
Averages	16.8	15.0	5.8	15.0	2.7	10.6	61	75	12

the other four varieties in the unsprayed series, but again spraying reduced the loss to a greater extent than in the case of other varieties. Cobourg showed the largest percentage of culls on the sprayed plants when the results of three experiments were averaged. As would be expected, the yield of salable fruit was increased to the greatest extent by spraying Garden State, since the control of fruit rots was greatest in that variety.

SUMMARY

Preliminary tests on the control of tomato anthracnose indicated that not all varieties were equally susceptible to the disease.

In 1944, 13 varieties were planted in two-row plots. The plots were arranged in random distribution with five replications. One row of each pair was sprayed with Fermate at 10-day intervals to determine the response of each variety to spraying. The same scheme was used for 15 varieties in 1945, for 48 varieties in 1946, and for 30 in 1947, except that Zerlate was substituted for Fermate during the last 3 years.

In 1944, Earliana showed the highest percentage of anthracnose-infected fruits (43.6 percent) and John Baer the lowest (14.2 percent). The average percentage of infection for all varieties was 23.8. Spraying reduced the disease by an average of 70 percent for all 13 varieties.

Anthracnose was less severe in 1945 than in 1944, and the average infection of unsprayed fruits was 6.6 percent. Bounty was the most susceptible variety, with 21.8 percent of the fruits infected. The average reduction in the disease by spraying was 77 percent.

In 1946, 48 varieties were included in the test. Although the season was dry, anthracnose was comparatively severe, and an average of 22.6 percent of the unsprayed fruits was diseased. Bison was most affected (70.2 percent); whereas a yellow variety, known as Gold Ball, with 3.9 percent infection showed the least anthracnose. Spraying reduced the disease by an average of 84 percent for all 48 varieties.

Pink varieties showed more anthracnose than red or yellow ones, the percentages affected being 25, 23, and 9, respectively. The pinks responded more to spraying than the reds or yellows.

Fruits produced on vines of determinate growth developed more anthracnose than those of indeterminate plants. The average percentage of infection on seven varieties of the former type was 35.8 and only 10.8 on the latter. Spraying the determinate varieties decreased anthracnose 85 percent and increased the yield of usable fruit by 71 percent.

The average percentage of anthracnose on seven early varieties was 38; on seven others of late maturity, it was only 15 percent.

Twenty-eight percent of the fruits produced on seven varieties with open vines and sparse foliage were affected; whereas this percentage dropped to 18 in an average of seven other varieties with more compact vines and denser foliage. Spraying increased the yield of the former varieties 66 percent and 45 percent on the latter. The average percentage of fruit infection on 14 varieties that were nearly defoliated on September 15 was 37, whereas only 17 percent was affected on another group of varieties which held their foliage longer.

There was little or no correlation between susceptibility of the fruit to infection by anthracnose and its resistance to mechanical puncture.

Thirty varieties were compared for susceptibility to anthracnose, and, incidentally, to late blight in 1947. Maximum infection by anthracnose occurred on varieties like Bounty, "651", Earliana, Jefferson, Gem, Earliana x Valiant, and Earliana x Rutgers. Spraying at seven weekly intervals with Zerlate reduced anthracnose by about 90 percent, late blight by 72 percent, and the cull fruits by approximately 64 percent. The total number of fruits set was increased 11 percent by spraying. Total fruit yield and the yield of usable fruit were increased by 30 and 95 percent, respectively.

When five commercial processing varieties were compared for susceptibility to anthracnose infection, it was found that Garden State showed the most disease, followed in decreasing order by Cobourg, Stokesdale, Rutgers, and Baltimore.

Garden State also showed the greatest increase in infection as the season advanced; in fact, it ranked first in this respect in another group of 15 varieties. Of the five commercial processing varieties, Garden State also showed the most favorable response to spraying with Zerlate for the control of anthracnose.

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